This Arkansas Water Science Center Hydroacoustic Quality-Assurance Plan documents the standards, policies, and procedures used for activities related to the collection, processing, storage, analysis, and publication of discharge measurement data.

Introduction

The U.S. Geological Survey (USGS) was established by an act of Congress on March 3, 1879, to provide a permanent Federal agency to perform the systematic and scientific "classification of the public lands, and examination of the geologic structure, mineral resources, and products of the national domain." Surface-water activities in the Arkansas Water Science Center (ARWSC) are part of the Water Resources Discipline's (WRD) overall mission of appraising the Nation's water resources. Surface-water information, including streamflow, stage, and sediment data, is used at the Federal, State, and local levels for resources planning and management.

The purpose of this ARWSC Hydroacoustic Quality-Assurance Plan (QA Plan) is to document the standards, policies, and procedures used for activities related to the collection, processing, storage, analysis, and publication of hydroacoustic discharge measurement data.

This plan identifies responsibilities for ensuring that stated policies and procedures are carried out. The plan also serves as a guide for all ARWSC personnel involved in discharge measurement activities and as a resource for identifying memorandums, publications, and other literature that describe in more detail associated techniques and requirements.

The scope of this report includes discussions of the policies and procedures followed by the ARWSC for the collection, processing, analysis, storage, and publication of hydroacoustic discharge measurement data. In addition, issues related to the management of the computer data base and employee safety and training are presented. Although procedures and products of interpretive projects are subject to the criteria presented in this report, specific interpretive projects are required to have a separate and complete quality-assurance plan.

Use of Hydroacoustic Instruments

Hydroacoustic instruments are devices that use sound waves to measure water depth and velocity. They are relatively new instruments and work much differently that the traditional mechanical current meters. There are several reports and Memorandums covering the use of hydroacoustic instruments by USGS personnel, all of which are listed with other references and information at the USGS Hydroacoustics web site (http://hydroacoustics.usgs.gov).

The lead person in the Arkansas WSC for overall hydroacoustic operations is Kevin Hubbs. He will be responsible for keeping current on the latest developments in the field of inland hydroacoustic instruments, including changes in hardware and software and changes in USGS policies on their use. He

is responsible for writing and gathering feed back on local hydroacoustic policies and procedures, and will serve as a point of contact for questions on hydroacoustic instruments for personnel in the WSC. He also maintains the instrument history logs for the WSC's ADCPs.

Hydrographers that are trained to use ADCPs through the 'Measurement of Streamflow using ADCPs' in the ARWSC are as follows: Bill Baldwin, Elizabeth Beavers, Bob Blanchard, Bubba Brossett, Kevin Davis, Jeanne De Lanois, Steve Franks, Marsha Gipson, Jan Heavener, Kevin Hubbs, Walter Killion, Kane Martin, Collin Reinhardt, Dan Wagner, Joey Fleming, Dwight Lasker, Tyler Mays, and Ted Wallace. The hydrographers are responsible for understanding how the ADCPs work, know when and where an ADCP can be used, the limitations of the ADCP, and care and maintenance of the ADCPs. Hydrographers are responsible for making discharge measurements in accordance to OSW and ARWCS policies.

The ARWSC currently has one Teledyne RD Instruments Rio Grande 600 kHz, five Teledyne RD Instruments Rio Grande 1200 kHz, three Teledyne RD Instruments StreamPros, and 14 SonTek/YSI Flow Trackers, and one SonTek RiverSurveyor. There are 2 DGPS and one 200 kHz depth sounder that can be used with the ADCPs. The ARWSC currently has six Argonaut 1.5 MHz side lookers, and two Argonaut SW Doppler Current Meters for shallow water deployed. The Sontek RiverSurveyor should not be used for making discharge measurements.

ADCP Measurements

Acoustic Doppler Current Profilers (ADCPs) work much differently than traditional mechanical current meters. Users of ADCPs in the WSC must read all of the documents governing the use of ADCPs, and be acutely aware of the policies and procedures related to ADCP use in the USGS and the ARWSC. According to OSW Memorandum 2002.02, USGS personnel collecting and reviewing ADCP data are required to have completed the USGS training class *Measurements of Streamflow using ADCPs*.

USGS Office of Surface Water Policy Memorandums and Reports

The guidance in the following USGS Memorandums should be followed by WSC personnel:

1. OSW Memorandum 2002.02 Policy and Technical Guidance on Discharge Measurements using Acoustic Doppler Current Profilers.

2. OSW Memorandum 2005.05 Guidance on the use of RD Instruments StreamPro Acoustic Doppler Profiler.

3. OSW Memorandum 2005.08 Policy and Guidance for Archiving Electronic Discharge Measurement Data.

4. OSW Memorandum 2005.09 Classifying Measurement Type in the Automated Data Processing System (ADAPS).

5. OSW Memorandum 2006.02 Quality-Assurance Plan for Discharge Measurements Using Acoustic Doppler Current Profilers (Scientific Investigations Report 2005-5183).

6. OSW Memorandum 2006.04 Availability of the report "Application of the Loop Method for Correcting Acoustic Doppler Current Profiler Discharge Measurements Biased by Sediment Transport" by David S. Mueller and Chad R. Wagner (Scientific Investigations Report 2006-5079) and guidance on the application of the Loop Method.

7. OSW Memorandum 2008.01 Release of WinRiver II Software (version 2.00) for Computing Streamflow from Acoustic Profiler Data.

8. OSW Memorandum 2008.02 Upgrade for Rio Grande/Workhorse Firmware to Address Potential Bias in Discharges Measured Using Water Mode 12.

9. OSW Memorandum 2009.02 Release of WinRiver II Software (version 2.04 for Computing Streamflow from Acoustic Doppler Current Profiler Data.

10. OSW Memorandum 2009.04 Application of FlowTracker firmware and software mounting correction factor for potential bias.

11. OSW Memorandum 2009.05 Publication of the Techniques and Methods Report Book 3-Section A22, *"Measuring Discharge with Acoustic Doppler Current Profilers from a Moving Boat"* and associated policy and guidance for moving boat discharge measurements.

12. OSW Memorandum 2010.02 Flow Meter Quality-Assurance Check - SonTek/YSI FlowTracker Acoustic Doppler Velocimeter.

13. OSW Memorandum 2010.07 Independent Water Temperature Measurement for Hydroacoustic Measurements

Training

A variety of training opportunities in hydroacoustics have been developed by the USGS, Office of Surface Water. These include formal training classes, short courses, workshops, and occasional Web-based seminars. Formal training courses are scheduled each year and include basic, advanced, and review classes

The USGS provides several other opportunities for less formal training activities. These include some Web-based training, workshops, and short courses offered periodically.

Wading Discharge Measurements (Flowtracker)

A CD-ROM based training class called "Measurement of Stream Discharge by Wading", has been developed by K. Michael Nolan and Ronald R. Shields. This course contains a section that covers the use of the Flowtracker for making wading discharge measurements.

Short Courses

The OSW offers short courses periodically, often in conjunction with the Hydroacoustics Workshop and meetings such as regional data conferences. These short courses are usually announced in conjunction with these conferences. They include such topics as "Techniques for Reviewing ADCP Discharge Measurements", "Complex Index Velocity Ratings", "StreamPro Policies and Procedures", "Use of Flowtracker", and "Best Practices for ADCP Measurements".

USGS Hydroacoustic Mailing List and Forums

The USGS, Office of Surface Water (OSW) maintains a mailing list and the Hydroacoustic Community forum relating to the application of acoustic instruments and methods for measurement of streamflow, velocity, and other hydraulic parameters in rivers and estuaries. The mailing list and forum are used to share information about acoustic instruments, including policies, procedures, techniques, and new developments within the USGS and other agencies.

Hydroacoustics Forums

The Hydroacoustics Community forum is maintained by the USGS, OSW for sharing information regarding the application of acoustics to the measurement of streamflow, water velocity, and other hydraulic parameters. The forum is a USGS resource to educate, learn, and facilitate the exchange of information about applications involving a variety of hydroacoustic instruments including acoustic Doppler current profilers (ADCPs), side-looking acoustic profilers, acoustic velocity meters (AVMs), and

acoustic doppler velocimeters (ADVs). The forums are also used by the USGS to disseminate important information regarding quality assurance practices, training, and other matters.

Registration is required to access the forum. Detailed instructions on registering can be found at http://hydroacoustics.usgs.gov/software/Forum_Reg1.html.

Acoustics Mailing List

The acoustics mailing list is the primary means for disseminating up-to-date information regarding USGS policies, training classes, workshops, and new developments. A searchable archive of email messages sent to the acoustics mailing list is kept. This archive can be viewed chronologically or by author or subject. In order to post to the acoustics mailing list, it is necessary to first subscribe to the list. There are two ways to subscribe:

1. Subscribe via your Web browser by going to the acoustics list information page. Complete the section of the form titled "Subscribing to Acoustics" and clicking on the "Subscribe" button.

2. Send email to acoustics-request@simon.er.usgs.gov with the words "subscribe" and "end" on separate lines in the body of the email. A confirmation email will be sent to you once you are subscribed. Email postings to the list should then be addressed to acoustics@simon.er.usgs.gov

ADCP Quality Assurance/Office Documentation

Office Documentaion

1. Training Records for employees/ADCP crew leaders.

2. Logs of ADCP/ADP instrument calibration checks (annual instrument checks or checks of a newly acquired instrument) The path to these checks is as follows: \\Igskedcwfsfiles\surface water information\ADCP_info\ADCP Annual Check
3. For each ADCP, a “history” log that includes model and frequency, acquisition date, firmware/hardware upgrade descriptions and dates. An electronic copy is kept at \\Igskedcwfsfiles\surface water information\ADCP_info\ADCP history

    - Training materials and other technical documentation are kept in the following directory: \\Igskedcwfsfiles\surface water information\ADCP_info

Pre-Field Office Procedures

1. **Selection of station for measurement**
    a) A list of priorities for measurement is located at http://ar.water.usgs.gov/district/safety/Flood_Plan.doc

b) Every site in the network should be measured at least six times yearly, more often if the site was resently installed, cooperator has need for additional data, or if there are gaps in the rating curve.

2. Regulations

a) Due to the unique conditions at several sites located downstream of dams, it may be possible to regulate structures (gates, pumps, locks, etc.) to obtain various flow and velocity conditions within a single day. This multiple-flow condition potential should be considered and/or attempted any time a discharge measurement is planned pending approval by US Army Corps of Engineers (USACE), or Electric Company water managers.

b) Based on water and environmental conditions, contacts will let you know what control conditions are possible on a given day. Careful coordination and communication is necessary for these types of measurements.

3. Project considerations

a) Due to the varying nature of projects using ADCPs for discharge measurements, each project should establish a set of pre-field office procedures and protocols, especially concerning measurement station selection.

4. Before Leaving for a Site

a) The most recent firmware and software versions should be installed on all field instruments before measuring. As of 8/10/2010:

i) For ADCP discharge measurements, the most recent software version of WinRiver II is version v2.04. The most recent firmware upgrades for the RioGrande ADCP is version 10.16.

ii) For the ADP the most recent software version is RiverSurveyor v4.60. The most recent firmware upgrade is v8.8. The most recent communications and diagnostic software is SonUtils v4.20.

iii) For the ADV the most recent software version is Flowtracker v2.20. The most recent firmware is v3.7.

iv) For the StreamPro recent software versions v3.31. The most recent firmware verion is v31.04.

v) For the Sontek Argonaut SL the most recent firmware is v11.9.

vi) The latest version of these is located on the OSW webpage http://hydroacoustics.usgs.gov/software/index.html

b) Know the site you are going to. Due to depth constraints with the 1200 Rio Grande, and limitation of wading, it is important to know the channel depth range, so appropriate equipment can be taken to the field. Review previous 9-207 files and current DCP water levels to understand current conditions. Also bring a copy of the station description for specifics at the site.

c) Use the ADCP checklist of equipment to bring into the field. Figure 1.

d) The ADCP, cables, connectors, batteries, mounts, and DGPS or echo sounders that will be integrated with the ADCP in the field should be inspected physically for any irregularities. The ADCP should be connected to the field computer, and communications with the ADCP established using the ADCP data-collection software. This would be a good time to reset the clock using a handheld GPS.
e) A self-test should be run to make sure the ADCP is working properly. Note: There are certain tests that might fail when the ADCP is out of the water.
f) If radio modems are to be used for communications (tethered and remote-controlled platform deployments) communications should be established using the radio modems. If a DGPS or echo sounder is to be connected to the ADCP in the field, then testing of all equipment prior to leaving for the field should occur.
g) If problems are encountered during any system check, the problems should be resolved by:
    i) consulting the necessary technical documentation,
    ii) consutling other hydrographers in the office,
    iii) calling an OSW representative,
    iv) calling the vendor technical support unit.

Field Procedures

A summary of important new policies is provided below.

1. For every discharge measurement, the temperature measured by the ADCP must be compared with an independent water temperature measurement made adjacent to the ADCP and recorded on the field measurement form.

2. Every moving-boat discharge measurement made with an ADCP must have a recorded moving-bed test (MBT), even if a Global Positioning System (GPS) is used with the ADCP.

3. The loop MBT is preferred if conditions permit, but stationary MBTs are acceptable. The criteria for the loop MBT as described in OSW Technical Memorandum 2006.02 remains unchanged; however, the criteria for a stationary MBT have changed.

4. For stationary MBTs where the ADCP deployment is anchored, tethered, or has GPS data collected simultaneously, the duration of the stationary MBT must be at least 5 minutes; otherwise the duration of stationary MBTs must be at least 10 minutes.

1. **ADCP field measurement procedures are documented in:**
   a) "Techniques and Methods 3-A22 "Measuring Discharge with Acoustic Doppler Current Profilers from a Moving Boat"; this report describes ADCP boat deployments, instrument setup, site selection, and proper discharge measurement techniques;
   b) OSW Technical Memorandum 2009.05; this memorandum provides specific policy and technical guidance for making ADCP field measurements. The OSW class users manual "Measurement of Streamflow using ADCP's".
2. **Auxillary data**
   a) A range check at an ADVM site should be done before the measurement to assure a clear cross-section.
   b) If an ADVM is at the site, it should be set up to record internally every three minutes, averaging for three minutes.
   c) DCP stage readings during the measurement should be noted.
   d) After the discharge measurement is made, all data should be downloaded, and stored on the ARWSC server \\Igskedcwfsfiles\surface water information\DARLRK-RawData.
3. **ADCP mounting considerations**
   a) The ADCP mount used by the ARWSC is mounted on the right front of the boat.
   b) An appropriate mount should:
      i) allow the ADCP transducers to be positioned free and clear of the boat hull and mount;
      ii) hold the ADCP in a fixed, vertical position so that the transducers are submerged at all times while minimizing air entrainment under the transducers;
      iii) allow the user to adjust the ADCP depth easily;
      iv) be rigid enough to withstand the force of water caused by the combined water and boat speed;
      v) be constructed of non-ferrous material;
      vi) be adjustable for pitch and roll; and,
      vii) be equipped with a safety line to hold the ADCP in the event of a mount failure.
4. **Measurement Cross-section Selection**
   a) Desirable measurement sections are usually either parabolic or trapezoidal. A broadband ADCP may experience interference on the sides if the cross-section is rectangular. Asymmetric channel geometries (for example, deep on one side and shallow on the other) should be avoided if possible (Techniques and Methods 3-A22), as should cross-sections with sharp channel-bottom slope changes such as rapid drop-offs.
   b) Measurement sections with average velocities less than 0.30 ft/s (feet per second) should be avoided if possible. Although discharge measurements can be made in such conditions, boat speeds must be kept extremely slow requiring special techniques for boat control such as

establishing mandatory tag lines and avoiding windy conditions. (Techniques and Methods 3-A22).

c) The most preferable stream bed cross-section should be as uniform as possible and free from debris and vegetative growth. Measurement sections with debris, excessive aquatic vegetation, or snags should be avoided.

d) Depth at the measurement site should allow for the measurement of velocity in two or more depth cells.

e) Sites with highly turbulent flow should be avoided, as this is often indicative of non-homogenous flow. A condition with excessive turbulence can violate one of the assumptions in using ADCPs for velocity and discharge measurements of homogenous flow (water velocity magnitude and direction is the same in all ADCP beams).

f) Measurement sections in local magnetic field disruptions caused by steel structures or transmission lines should be avoided as they may cause ADCP compass errors.

g) When using a DGPS, avoid locations where multi-path interferences occur (signals from the satellites bounce off structures and objects such as building or trees) or where reception of signals from GPS satellites is blocked or weak.

h) Measurements made at gate and pump sites should be made on the upstream side to avoid the large turbulence downstream. An exception can be made if the measuring section is far enough downstream of the structure. Care must be taken to observe and include any inflows or outflows between the structure and measurement section.

i) Piers are known to have an effect on flow distribution and can cause turbulence downstream. Whenever possible, measuring on the upstream side of a bridge is preferred.

j) Measuring in close proximity upstream of a constriction can cause turbulence if you are too close. Measurement sections near steel structures such as bridge girders (that can cause ADCP compass errors) should be avoided.

k) It may be possible to make valid measurements in sections having one of more of the above features, but whenever possible, locate and use a better measurement section.

5. **Guidance for measurement modes**

a) All 1200 KHz ADCPs at the ARWSC are equipped with the following water modes (Mode 1, 5, 12SB, 12RB) and bottom modes 5 and 7.

b) The 600 KHz ADCP is equipped with water mode 1, 5, and bottom mode 5 only.

c) Some very basic guidelines for depth and water velocity are given in the following table

Limitations - Maximum Profiling Range

Mode	**1200**	**600**
1/12	65ft	200 ft
5	13ft	26ft

Maximum Relative Velocity

Mode	1200	600
1/12	33ft/s	33ft/s
5	1.6ft/s	3.2ft/s

6. **Measurement procedures**

a) The naming convention for all ADCP measurements is as follows

i) 4 letter associated with station name and *mmddyyyy* of measurement (example: NEWP03162007). If different modes were used or different channels were measured, then the filename should be changed (examples: NEWP203162007, NEWPRelief03162007).

b) The water temperature should be taken with a hand held probe and compared to the ADCP temperature. If there is a difference in temperatures, check the probe. It is recommended if the temperature is more than 2 degrees Celsius difference, the ADCP should be sent in for repair.

c) In order to see the depth of the ADCP in the water, all crew members should be in the position they will be at while making the discharge measurement. The depth is visible to the boat driver and should be noted on the field note sheet in the block labeled "profiler depth", prior to making the discharge measurement.

d) The ADCP clock must be checked against the clock of a handheld GPS and synchronized if necessary.

e) The 9-275-I discharge field form is the proper OSW form to use for ADCP discharge measurements. An ADCP self test (RGTest.exe) must be performed. If any of the tests fail, a note must be made on the 9-275-I discharge form. At some sites, the receive bandwidth fails some of the time. This is considered to be a function of interference at the site and is not cause to abort the discharge measurement. It will not adversely affect the product output.

f) A moving bed test must be performed prior to each discharge measurement. One of two methods can be used, a Loop Moving Bed test or a Stationary moving bottom test. A stationary moving bed test must be performed for 10 minutes at the section with the highest velocity. When the stationary moving bed test is performed, if a moving bed is indicated, then the Loop test must be performed as well. The transect number should be well documented. See Scientific Investigations Report 2006-5079 *Application of the Loop Method for Correcting Acoustic Doppler Current profiler Discharge Measurements Biased by Sediment Transport*, and, *Loop Moving Bed Test Field Procedures*.

g) If any additional commands are added to the configuration file this should be clearly noted on the 9-275-I discharge form.

h) To begin and end transects a minimum of two bins and ten ensembles are needed for a good side estimate.

i) Whenever possible, boat speed should not exceed water speed.

j) Abrupt changes in boat direction or speed should be avoided

k) Watch velocity magnitude plots on the laptop to spot any problems such as unusual velocities, a large amount of missing ensembles or bins, or biases on the sides or bottom.

l) Do not move too much in the boat while making the discharge measurement. Small movements can affect the pitch and roll.

m) When making an ADCP discharge measurement, the operator should continuously monitor the data. If a critical data-quality problem is observed during a transect, the transect must be terminated. Potential critical data-quality problems can include:

i) use of an operating mode inappropriate for the site;

ii) configuration errors, such as an insufficient number of depth cells to profile to the channel bed;

iii) excessive number of bad or lost ensembles/profiles or depth cells;

iv) excessive number of ambiguity errors (see Simpson (2002) for explanation of ambiguity errors);

v) excessive boat speed; and,

vi) inadvertent early termination of the transect.

vii) The width of the section should be very similar each time a transect is made.

n) Document the starting and stopping locations in each section so constantancy is kept and a good side distance can be attained. If the stage is rising or falling, document how it might be affecting the edge estimates.

o) Document the shape of the banks. If one bank is steeper than the other, it may be appropriate to use different edge coefficients and change the defaults. Viewing the graph of the cross-section area may help determine a coefficient to use when working up the data at the office.

p) Wind conditions can drastically affect a slow moving stream, and, in turn, selection of the unmeasured top section estimating extrapolation technique. If wind conditions change throughout the discharge measurement, make notes of direction and magnitude.

q) Before breaking down after the discharge measurement, the discharge history table should be examined for any potential problems.

r) OSW policy states that four discharge transects make a measurement and that each transect should agree within 5%. If measuring at an assumed steady state condition and the four transects do not agree within 5% another four transects must be made. This agrees with OSW policy, and if the changing conditions are real, more conditions are obtained in the field and the stage sensors should show this change.

7. **Post measurement field procedures**

a) If the stage changed drastically, remeasure the edge estimates.

b) If this is a multi-day field trip, the data must be backed up onto a CD or USB storage device.

c) A final inspection of the DCP is necessary after each discharge measurement.

d) Complete discharge measurement notes at the site.

8. **ADV field measurement procedures are documented in: OSW Technical Memorandum 2007.01, and OSW Technical Memorandum 2004.04.**

(1) Assemble the ADV on a wading rod.

(2) Vent the cap. The Flowtracker is completely sealed, and needs to be vented prior to each discharge measurement. This is done by loosening the cap on the external communications connector a few turns. Pressure will equalize within a few seconds, and the cap can be tightened. The reason that this step is necessary is that changes in temperature and/or atmospheric pressure can cause a difference in internal and external pressure that may affect keypad operation or system operation.

(3) Power the ADV on.

(4) Check the batteries and ADV time. Change as needed.

(5) Start the data run. For more information on using and operating an ADV see *FlowTracker Technical Documentation* 6054-60007.

(6) The station name should be the station number (example 07363000).

(7) The extention should be the measurement number (example 047).

(8) Site should be name or letters associated with the site name (example Benton).

(9) Follow standard wading measurement procedures listed in Water Supply Paper 2175, OSW Technical Memorandum 2007.01, and OSW Technical Memorandum 2004.04.

(10) When the discharge measurement is complete, measurement information should be documented immediately on on a field note sheet (Form 9-275G Discharge Measurement and Gage Inspection Notes).

(11) After measurement information is documented, exit back to the main menu before powering the ADV off.

Post-Field Office Procedures

9. **Post-Measurement Office Procedures**

a) The Q measurement wizard should be used every time a group of discharge measurements are to be made in the same general condition (if the depth or velocity does not change enough to warrant the use of a different water mode).

b) The ADCP and associated accessories (DGPS, vertical depth sounders, tethered boat, electronic rangefinders) should be inspected upon returning from the field to determine the condition of all components. Deployment platforms and mounts should also be inspected. Damage or undue wear to any of the instruments or their components, deployment platforms, tethered boat, or mounts should be repaired as soon as possible. The ADCP, all accessories, platforms (tethered or motorized boat), mounts, and field computers should be prepared for redeployment and stored in appropriate locations.

c) Electronic data is required to be stored in the proper directories (see data archiving section III) *Data that is to be stored in the directory is as follows:*

i) *All WinRiver transect files*

ii) Q-wizzard file (.dmw)

iii) ADCP self-test

iv) Compass calibration and pressure calibration (if performed)

v) Files downloaded from the Acoustic Velocity Meters (AVM)

vi) Text files converted from the AVM file

vii) Range check files from the AVM

viii) All ADV files and ADV check files

ix) Any other auxiliary data from external units such as the DGPS or depth sounder

d) For multi-day field trips, all above data should be backed up onto portable storage units such as CD or USB storage device.

e) Each discharge measurement should be entered into SiteVisit and then filed in appropriate office folders (in Little Rock the daily and partial site office folders are located behind and to the left of the PS printer, ADEQ discharge measurements are filed in the Map Room)

i) Each discharge measurement should have a completed front sheet.

ii) Each discharge measurement should have a printout from Q-wizard or FlowTracker attached to the front sheet.

iii) Any field notes or computations (how reliefs were estimated, change in stage…) should also be attached to measurement front sheet.

f) General guidelines of ADCP computation are discussed below. More complete discussions can be found in the ADCP training materials

i) The discharge measurement note sheets should be complete, clear, legible, and neat.

ii) All electronic data files associated with the measurement should be backed up in the field and archived on an office server (\\Igskedcwfsfiles\surface water information\DARLRK-RawData).

iii) The number of transects collected should be appropriate for the flow conditions and satisfy OSW policy. Transects should have been collected in reciprocal pairs or noted if this way was not possible.

iv) Configuration files should be checked for errors, appropriateness for the hydrologic conditions, and for consistency with field notes. Noted transducer drafts, salinity, edge distances, edge shapes, extrapolation methods, and ADCP configuration parameters should match those in the configuration file.

v) A stationary moving bed test of 10 minutes in length and/or a loop moving bed test should have been performed prior to each discharge measurement, these should be recorded, archived, and noted on the ADCP measurement note sheets. If a moving bed

was detected, DGPS must be used; if not, the measurement quality should be downgraded. The LC software must be utilized with the Loop moving bed test for some corrections. SMBA program is also used to process the stationary test. This will help to give it a better discharge number.

vi) The average boat speed for the measurement should not exceed the average water speed. Boat pitch and roll should not be excessive. Excessive boat speed or pitch and roll may justify downgrading the measurement quality.

vii) Edge distances were physically measured and the distances noted on the ADCP measurement note sheet should match those electronically logged with each transect. The correct edge-shape should be selected, and 5-10 seconds of data collected at the transect stop/start points while the boat is held stationary. If subsectioning was used to correct problems with edges, the subsectioning should be clearly documented on note sheets. If vertical walls were present, the transect start/end points should be at least one depth unit away from the walls.

viii) There should not be excessive loss of ensembles/profiles. The loss of more than 10 percent of ensembles/profiles in one or more transects may necessitate downgrading the measurement, especially if the missing data are mostly in one section of the transect. When less than 10 percent of the ensembles/profiles are missing, but always occur in the same part of the transect, the measurement quality should be downgraded.

ix) When more than 25 percent of the depth cells in one or more transects are marked invalid or missing, the quality of the measurement may need to be downgraded. However, this is not necessary if the distribution of the missing depth cells is more or less uniform throughout the water column.

x) The extrapolation method for the top and bottom discharges should be reviewed. If review of the data indicates the need for a different extrapolation method, the extrapolation method should be corrected and the reasons documented on (or attached to) the measurement note sheet. Wind and horizontally-stratified density currents are common causes for profiles that are not fit well by means of the $1/6^{th}$ power law. In these situations, it is usually necessary to use different extrapolation techniques for the top and bottom areas and (or) to limit the portion of the profile used for the selected method.

xi) It may be necessary for the person that made the discharge measurement or the reviewer to change some configuration parameters. It may be necessary to subsection the transects to provide a more accurate estimate of the edge discharge (for example, when there is excessive boat movement in the data used to estimate the edges). Changes to configuration parameters could include correcting the ADCP depth or the extrapolation method for top and/or bottom. If the reviewer makes changes, these should be discussed with the person who made the discharge measurement.

xii) Any changes to the configuration parameters and the reasons for the changes must be documented on (or attached to) the ADCP measurement note sheets.

g) Discharge measurements should be reviewed in detail as soon as practical,

i) If the person responsible for the site was making the discharge measurement, they should be responsible for computing the discharge measurement. A second qualified reviewer should check the ADCP measurement as soon as scheduling allows.

ii) If the person responsible for the gaging station was not at the site, they should be responsible for checking the measurement. The person who made the measurement should be responsible for its computation.

iii) If the person responsible for the site does not have ADCP computation experience, the measurement may be checked by any available qualified person.

iv) Figure 2 contains the outline for Review of WinRiver Data Files. This outline should be followed when checking an ADCP measurement.

v) ADV measurements should be scanned for errors when values were entered in the field.

h) If a particular procedure was not followed completely, or if the discharge measurement itself fails a particular criteria, it is advisable to downgrade the quality of the measurement. This should be clearly noted on the discharge measurement form.

i) Especially for varying velocity sites when multiple conditions were obtained throughout the day, measurement numbers are not assigned to transects until the auxiliary data are processed. OSW Technical Memorandum 2002.02 states that four transects across the channal make up one discharge measurement. Due to rapidly changing conditions prevalent at some sites, the change in discharge may correspond to a real change in velocity. A careful review of the auxiliary data will determine what transects are to be averaged. Transect averaging should follow the following protocol;

i) Averaged transects should be made right after each other and within a reasonable timeframe. If a large period of time passes between transects, then those transects should not be averaged, but are considered separate measurements.

ii) Specific for velocity-index sites

(1) The velocity difference in each transect should be no more than 0.05 ft/sec or 5%, whichever is greater

(2) The stage should vary by no more than 0.1 ft

iii) Specific for gated structure sites

(1) The gate opening should be the same for all transects

(2) The stage should vary no more than .05 ft

j) Once it has been determined which transects are to constitute one single discharge measurement, the Q-summary in WinRiver must be filled out. Instead of using the default name it provides, the name should use the following form: four letters associated with station, *mmddyyyy* of measurement and, measurement number (example NEWP08302007_304). One discharge measurement form needs to be filled out for each measurement. These forms should be saved in to the same directory as all other ADCP files.

k) The final ADCP measurement should contain all of the following

(1) OSW approved front sheet (form 9-275-I Acoustic Profiler Discharge Measurement Notes)

(2) Any office computation

(3) Q-wizard electronic output summary sheet

(4) Stage/Velocity summary output.

(5) ADCP diagnostics

ii) Possible considerations for what should reside with ADCP measurement notes folder:

(1) ADCP narrative

(2) Data page

(3) Summary output page (regression statistics and measurement info)

10. **Instrument Calibration Checks**

a) Each ADCP used by USGS offices must be tested:

i) when the ADCP is first acquired;

ii) after factory repair and prior to any data collection;

iii) after firmware or hardware upgrades and prior to any data collection

iv) Annually

b) Annual calibration checks should

i) Include all ADCPs used for data collection

ii) Include all water modes and bottom modes used in data collection

iii) Be made at a site with a good stable rating

iv) Be at a site where it is possible to get a large variation in conditions

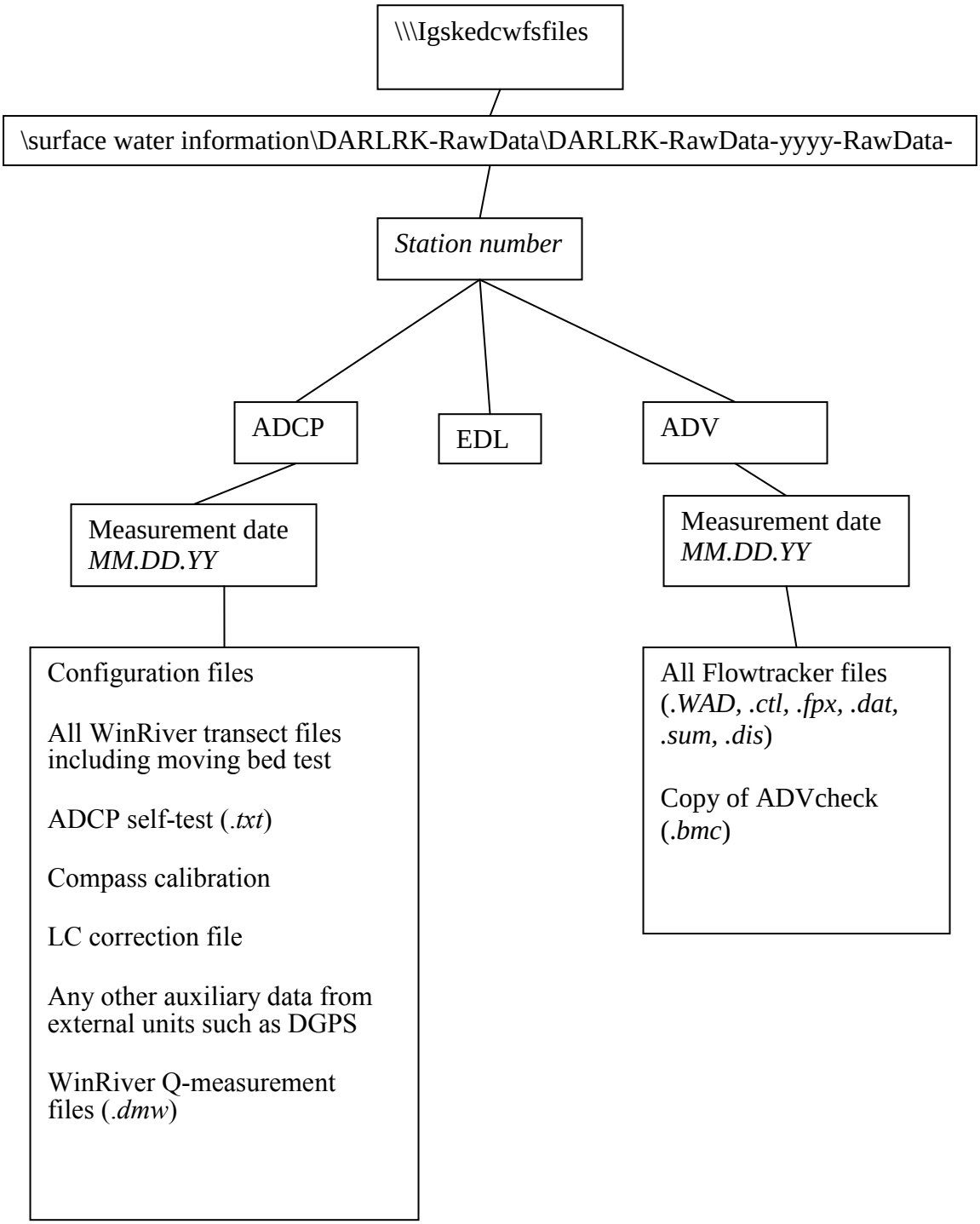
v) Be at a site where the 1200 ADCPs can easily use mode 5 (the depth is less than 12 feet.)

vi) Be at a site that is ideal (no vegetation, good banks, easy to access)

11. **Periodic Review**

a) Every 3 years, OSW personnel or their designees will review each office's procedures for ADCP measurements, documentation, and data archival during the District or Office of Surface Water Review (Lipscomb, 1995). This review will include an evaluation of site selection, suitability of configuration files, measurement completeness and accuracy, documentation of instrument diagnostic tests and moving bed checks, and archival of data files. The review will evaluate the maintenance procedures followed by each office to ensure that the most current firmware and software upgrades have been implemented, and that the instrument and peripheral equipment are being maintained properly. In addition, the review will evaluate the office ADCP quality-assurance plan to ensure it complies with OSW policies and that the plan is being implemented. The appropriate WSC or Office personnel will immediately address recommendations by the Surface Water Review team.

Data Archiving



Appendices

Figure 1

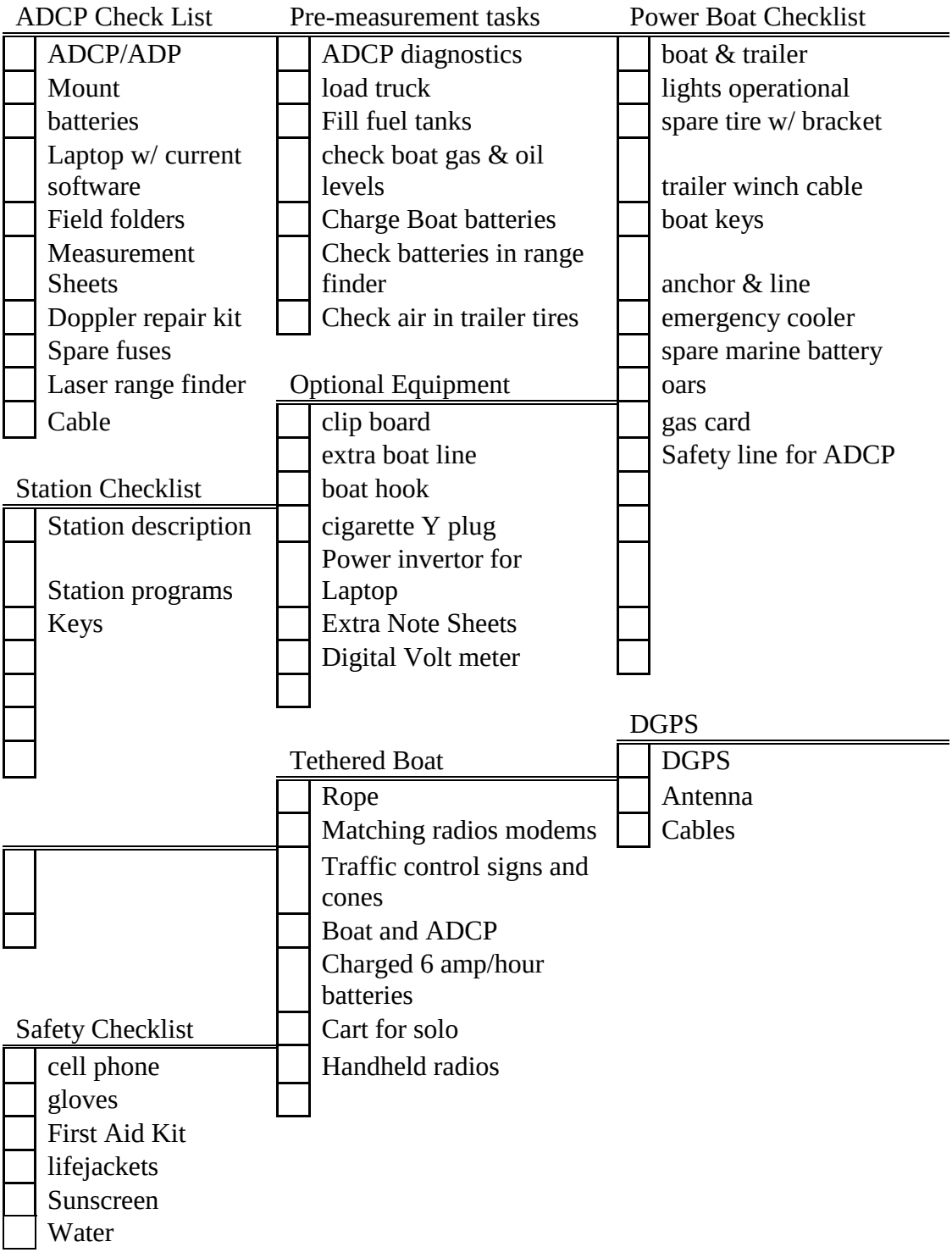
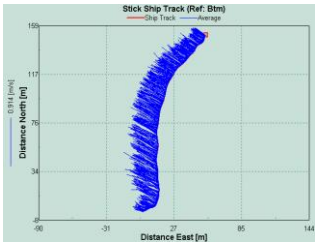


Figure 2

Outline for Review of WinRiver Data Files



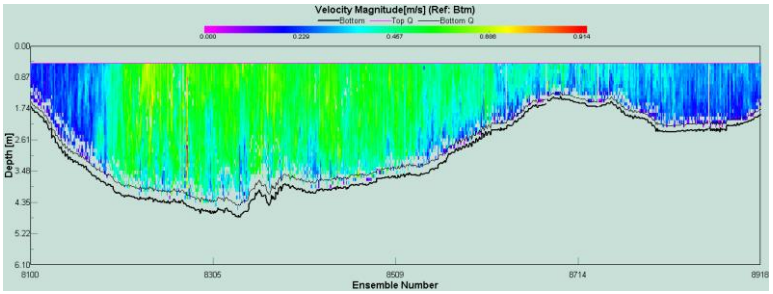
Outline for Review of WinRiver Data Files

1. Load Data

- Load rawdata file and play to end (Hit ***End*** key)

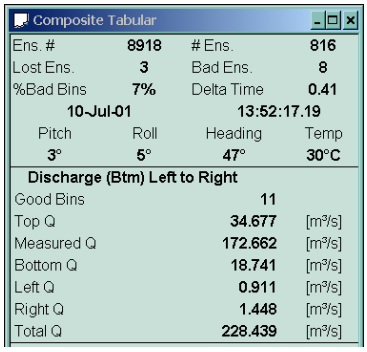
2. Check Ship Stick Plots

- Look at *ship stick plot*
- Verify velocity reference (BT or GGA)
- Step through depths using ↓ (if problems are observed, look at *velocity contour plots or intensity / back scatter plots*)



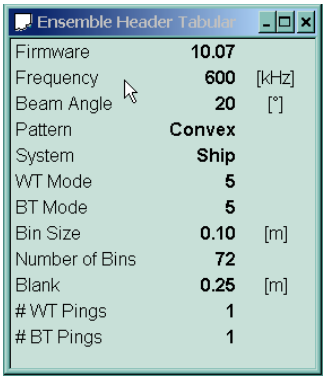
3. Velocity Magnitude Contour

- Review *velocity magnitude contour*. Scale as appropriate. Look for bad or missing data, bed contour, lost ensembles, etc.)



4. Composite Tabular.—Review:

- Number of Ensembles (total) vs:
  - (1) Bad ensembles
  - (2) Lost ensembles
- What is value for % Bad bins?
- Is water temperature realistic?
- Do the edge discharges appear reasonable?
- Do edge discharges have correct signs?



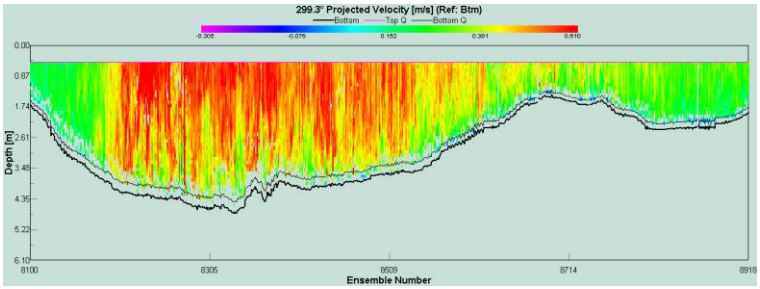
5. System Parameters

- Hit ***F9*** to check system parameters

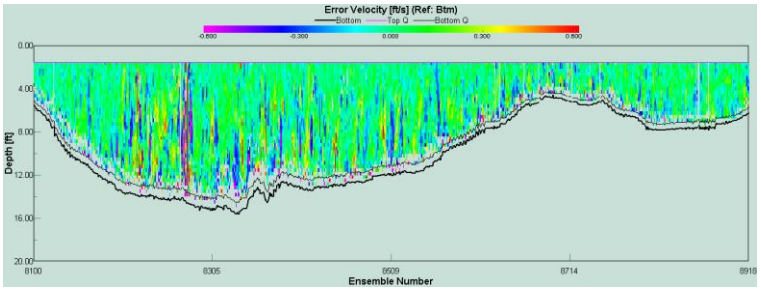
- Does the info there (Frequency, Firmware, Water and Bottom modes, Cell Size) match the direct commands (F3) specified in the config file?
- Does it match the field sheet?
-

6. Projected Velocity Contour Plot

- Hit ***F2*** to set angle for projected velocity contour plot and verify that value for the angle is correct. "Freeze" that value (for the first
- Transect – assuming that flow is uni-directional).



- Open *projected velocity contour plot*.
- Scale as appropriate
- Look for reverse / bi-directional flow

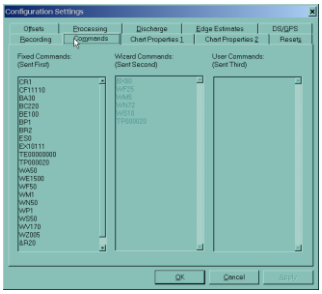


7. Error Velocity

- Open *error velocity contour plot*. Scale properly
- Look for ambiguity errors, 3-beam solutions. Outliers can be related to ambiguity errors or turbulence.

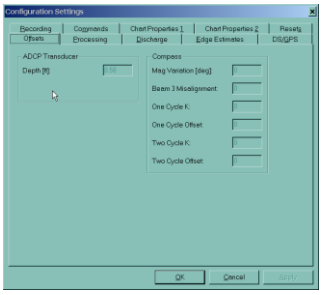
8. Configuration – Direct Commands

- Press ***F3*** and check direct commands (Wizard and User)
- Was the Config Wizard used?
- Are the Wizard and User commands set correctly for ADCP and flow conditions?



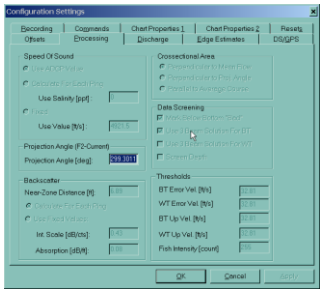
9. Configuration – Offsets

- Does the *Transducer depth* match the field sheet?
- Has *MagVar* been entered for Qm's made using GPS (GGA) as a reference?



10. Configuration – Processing

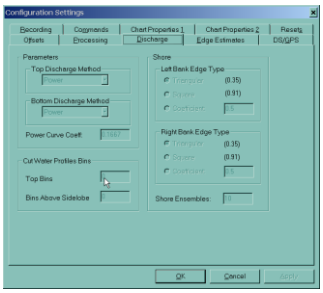
- Check area computation method
- Are thresholds used? If so are they used correctly?
- Is Salinity set correctly? Compare field sheet.



- Are 3-beam solutions for the water velocity (WT) data being used? (This is generally discouraged).

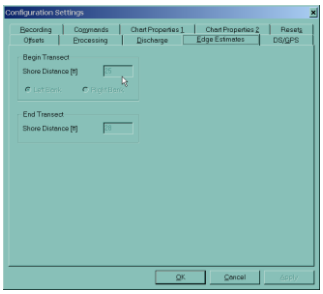
11. Configuration – Discharge

- Are *extrapolation methods* correct? See item 16.
- Review *edge types* selected.
- Was cutoff for water profiles used? If so, why and is it documented?
- Proper *shore ensembles* (10)?



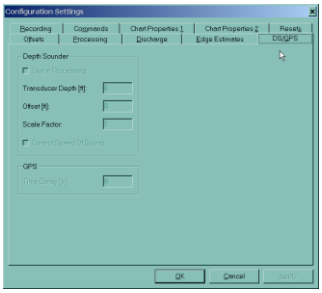
12. Configuration – Edge Estimates

- Are *Edge distances* consistent w/ field sheet? If not, has an explanation been supplied?
- Are *Edge distances* estimated rather than measured?
- Are the estimated edge discharges reasonable for this section?



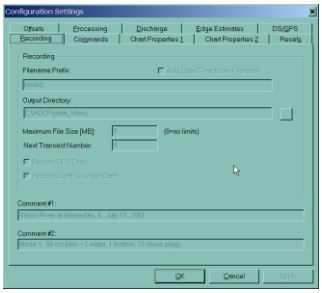
13. Configuration – DS/GPS

- Check to see if Depth sounder used



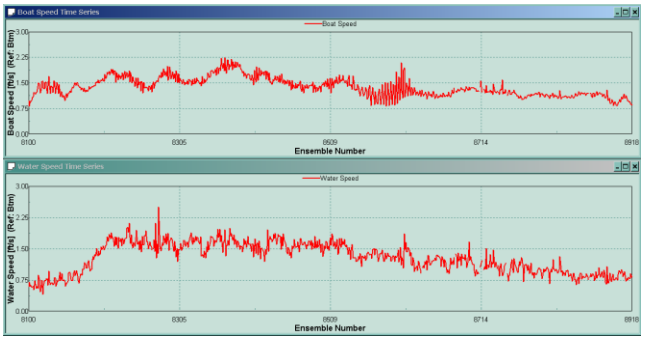
14. Configuration – Recording

- GPS recorded?
- Review comments field



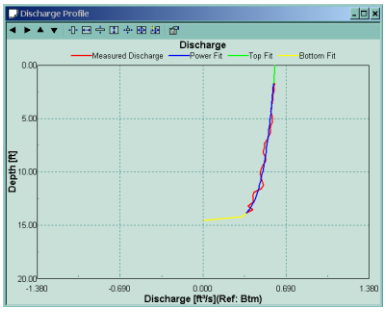
15. Time Series

- Review time series plots.
  - Compare *Water speed* and *Boat Speed* time series.
  - Review *Pitch / roll* plot for excessive pitch and roll
- Look for consistency, spikes, drop-outs, and large fluctuations.



16. Evaluate Extrapolation Method

- Open *Profile Discharge plot*
- Average 10-20 ensembles (***F7-Display Tab***)



- Use toolbar to zoom to data
- Modify extrapolation method as necessary

17. Repeat

- Replay all files for measurement

18. Check Whole Measurement

- Open *Discharge History Tabular* (***F12***)
- Are all discharges within 5%? In other words, are any lines red?
- Were reciprocal transect pairs obtained?
- Check the following for consistency
  - Total area
  - Widths
  - Boat speed
  - Flow direction
  - Duration
  - Compare boat speed to water speed

Example Discharge History Tabular for a "good" discharge measurement

Discharge History Tabular

File Name	# Ens.	Start Time	Total Q [ft³/s]	Start Bank	Left Dist. [ft]	Left Ens#	Left Q [ft³/s]	Top Q [ft³/s]	Meas. Q [ft³/s]	Bottom Q [ft³/s]
MARS269r.000	735	11:10:34	5848.358	Left	25.00	3698	13.400	900.061	4375.342	526.044
MARS270r.000	910	11:27:17	5806.111	Right	26.00	6887	21.127	899.622	4311.554	549.834
MARS271r.000	806	11:35:06	5966.820	Left	26.00	6921	15.861	903.238	4472.887	545.059
MARS272r.000	838	11:44:27	5890.810	Right	25.00	8958	20.641	914.997	4395.962	528.560
Average	822		5878.025				17.757	904.480	4388.936	537.374
Std. Dev.	73		68.556				3.753	7.194	66.508	11.837
Std./| Avg.|	0.09		0.01				0.21	0.01	0.02	0.02

Discharge History Tabular

Bottom Q [ft³/s]	Right Dist. [ft]	Right Ens#	Right Q [ft³/s]	Total Area [ft²]	Width [ft]	Boat Speed [ft/s]	Avg Course [°]	Q/Area [ft/s]	Flow Speed [ft/s]	Flow Dir. [°]
526.044	28.00	4465	33.511	5771.26	574.69	1.465	18.68	1.013	1.040	298.60
549.834	28.00	5951	23.974	5704.31	570.66	1.366	200.26	1.018	1.028	299.08
545.059	28.00	7720	29.776	5768.37	571.53	1.541	15.11	1.034	1.077	299.85
528.560	28.00	8119	30.649	5743.00	573.50	1.384	208.55	1.026	1.046	299.87
537.374			29.478	5746.73	572.60	1.439		1.023	1.048	
11.837			4.001	31.00	1.83	0.080		0.009	0.021	
0.02			0.14	0.01	0.00	0.06		0.01	0.02	

Example Discharge History Tabular for discharge measurement with “outliers”.

Discharge History Tabular

File Name	# Ens.	Start Time	Total Q [ft³/s]	Start Bank	Left Dist. [ft]	Left Ens#	Left Q [ft³/s]	Top Q [ft³/s]	Meas. Q [ft³/s]	Bottom Q [ft³/s]
MARS269r.000	735	11:10:34	5848.358	Left	25.00	3698	13.400	900.061	4375.342	526.044
MARS270r.000	910	11:27:17	5806.111	Right	26.00	6887	21.127	899.622	4311.554	549.834
MARS271r.000	806	11:35:06	5966.820	Left	26.00	6921	15.861	903.238	4472.887	545.059
MARS272r.000	838	11:44:27	5890.810	Right	25.00	8958	20.641	914.997	4395.962	528.560
MARS273r.000	737	11:51:38	6136.663	Left	25.00	9004	17.249	922.610	4635.525	527.250
MARS274r.000	799	12:43:36	7765.537	Right	25.00	933	28.403	1169.595	5883.429	642.922
Average	804		6235.716				19.447	951.687	4679.116	553.278
Std. Dev.	66		758.424				5.267	107.144	600.393	45.046

Field Procedures for Loop Test

Field Procedures for Loop Moving Bed Test

1. **Calibrate the ADCP compass.**
   Under the Acquire tab select execute compass calibration. Rotate boat in a slow counter clock wise circle. Click on Calibrate. Keep rotating boat. When this is complete, click on evaluate. When this is complete, boat rotation can be stopped. If the accuracy is less than 1 degree, you are done with calibration. Calibrations with errors greater than 1 degree should be repeated.

2. **Establish a marked starting point where the ADCP can be returned to the exact location.**
   This point is not required to be as near to a bank as the end of a regular transect. This is what the marker buoys are for.

3. **Make a steady pass back and forth across the stream as a standard discharge measurement, but do not stop recording at the far bank.**
   Keep a uniform boat speed. Plan the loop so that a smooth change in boat direction can be achieved near the far bank.

4. **Maintain the proper boat speed.**
   The recommended max boat speed should be the lesser of a boat speed that requires no less than 3 minutes to complete the loop or a boat speed that is less than 1.5 times the mean water speed.

5. **Return to the starting point.**
   Return to the exact location you started with. Accuracy is very important.

Water Temperature Measurements

It is OSW policy that the temperature measured by the ADCP must be compared with an independent water temperature measurement made adjacent to the ADCP. This check must be performed prior to every discharge measurement and the results recorded on the measurement field form. If the temperature measured by the ADCP temperature sensor differs consistently from the independent temperature measurement by 2 °C or more, or if the ADCP temperature sensor has failed, the ADCP should not be used to make discharge measurements until the temperature sensor is repaired and checked. In the event that a discharge measurement is necessary and another ADCP is not readily available, it may be possible to enter a temperature manually for use in the speed-of-sound calculations. This action is not recommended as standard practice; however, and it may decrease the accuracy of the discharge measurement (see page 18 of the subject T&M report).

Moving Bed Tests

Effective with the release of this report, every moving-boat discharge measurement made with an ADCP must have a recorded MBT. If a site routinely has a moving bed, and GPS is always used with the ADCP, an MBT is still required. The loop MBT is preferred if conditions permit; stationary MBTs are acceptable also.

For stationary MBTs, if the stationary position is maintained by a tether or anchor so that upstream or downstream movement of the ADCP is not possible, or when GPS data are collected simultaneously, the stationary MBT must be recorded for no less than 5 minutes; however, if the ADCP can move either upstream or downstream, such as when the boat operator is trying to maintain the position of the boat (without anchoring), the stationary MBT must be recorded for no less than 10 minutes. These criteria supersede the guidance on stationary MBTs that have been previously published in OSW Technical Memorandum 2002.02 and Oberg and others (2005).

If the stationary MBT was completed with a fixed tethered deployment, an anchored manned boat, or a manned boat where little movement of the boat was ensured, a moving-bed velocity greater than 1 percent of the mean water velocity at the test location indicates that a moving-bed condition exists. If the MBT was conducted using a manned boat that was not anchored and the boat may have moved either upstream or downstream, a criterion of 2 percent instead of 1 percent is used to determine if a moving-bed condition exists, because of the uncertainty introduced by the boat's movement.

OSW policy on the use of the loop method for doing MBTs is unchanged, but is restated here for convenience. When using the loop method, a moving-bed condition is determined to be present if the measured moving-bed velocity from the loop MBT exceeds 0.04 ft/s, http://water.usgs.gov/admin/memo/SW/sw06.04.html) and Mueller and Wagner (2006), and the moving-bed velocity is greater than 1 percent of the mean water velocity. The minimum duration for loop MBTs remains 3 minutes. For more information, see OSW Technical Memorandum 2006.04 (

If a moving-bed condition exists, discharge-measurement methods that are not affected by a moving bed (use of GPS for velocity reference), or methods that correct for the effect of a moving bed, must be used. Use of GPS is the preferred method for measuring discharge using ADCPs at sites where a moving-bed condition exists. If GPS is not available or it is not suitable for use due to site conditions, OSW recommends one of the following methods:

1. Loop method with distributed correction method (implemented in the Loop Correction (LC) program),
2. Multiple stationary moving-bed tests and distributed method using the Stationary Moving-Bed Analysis (SMBA) program, or
3. Mid-section method using ADCPs.

It is OSW policy that the LC software must be used to apply corrections for loop MBTs. Corrections based on stationary MBTs should be applied using the SMBA software (Mueller and others, 2009) unless site conditions do not meet the assumptions in SMBA (that higher moving-bed velocities are associated with higher near-bed water velocities). If the assumptions in SMBA do not apply to a particular site, the hydrographer is responsible for documenting the logic and computations used to apply a discharge correction from the stationary MBTs. For more information on these methods, including details as to their application and the detection of a moving-bed condition, please see Appendix B of the subject T&M report.

Beam Alignment Tests

A beam alignment test is described in the subject T&M report and by Oberg and others (2005). This test is useful for detecting beam misalignment errors in ADCPs equipped with a compass and such errors will result in biased velocity measurements.

Each ADCP equipped with a compass used by USGS offices for measurements of streamflow must be tested: (1) when the ADCP is first acquired; (2) after factory repair and prior to any data collection; (3) after firmware or hardware upgrades and prior to any data collection; and (4) every three years. The tests should be conducted on a lake or a stream where a moving-bed condition does not exist and where the ADCP can be used to obtain accurate bottom-track data (for example, not too shallow or too deep for bottom tracking). A sub-meter GPS should be used in conjunction with the ADCP. For any USGS office that does not own a suitable GPS, the USGS Hydrologic Instrumentation Facility will rent them to the offices. It is NOT necessary to do a compass calibration prior to conducting the tests. For a detailed description of the test and interpreting results, see Appendix D of the subject T&M report.

If you have any questions or comments about the policies and guidance in this memo, please contact Kevin Oberg (kaoberg@usgs.gov), Dave Mueller (dmueller@usgs.gov), Chad Wagner (cwagner@usgs.gov), or the OSW Hydroacoustics Work Group (hawg@simon.er.usgs.gov).

/signed/
Stephen F. Blanchard
Chief, Office of Surface Water

References

Mueller, D.S., and Wagner, C.R., 2006, Application of the Loop Method for Correcting Acoustic Doppler Current Profiler Discharge Measurements Biased by Sediment Transport: U.S. Geological Survey Scientific Investigations Report 2006-5079, 18 p. available at http://pubs.usgs.gov/sir/2006/5079/

Mueller, D.S., and Wagner, C.R., 2009, Measuring discharge with acoustic Doppler current profilers from a moving boat: U.S. Geological Survey Techniques and Methods 3A–22, 72 p. (available online at http://pubs.water.usgs.gov/tm3a22)

Mueller, D.S., Rehmel, M.S., and Wagner, C.R., 2009, Using a StreamPro Acoustic Doppler Current Profiler in Moving-Bed Conditions: Problems and Solutions: Proceedings of the 33rd IAHR Congress, Vancouver, Canada, American Society of Civil Engineers, in press

Oberg, K.A., Morlock, S.E., and Caldwell, W.S. 2005, Quality-assurance plan for discharge measurements using acoustic Doppler current profilers: U.S. Geological Survey Scientific Investigations Rep. 2005-5183, 44 pp. (available online at http://pubs.usgs.gov/sir/2005/5183/)